

Seminar on

Diffraction Optics and Nanophotonics: Resolution Below the Diffraction Limit

by

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Time : Session 1: 11:00 am to 12:00 noon; Session 2: 05:00 pm to 06:00 pm
Venue : Room 15-202, 15/F, meeting room of State Key Laboratory of Millimeter Waves,
15/F, Academic 3, City University of Hong Kong

Abstract

The seminar will be talked about the developments included in the book "Diffraction Optics and Nanophotonics: Resolution Below the Diffraction Limit" written by the speakers. The major limitation of contemporary imaging systems is based on the diffraction limit of light. The physical meaning of this limit is that the light cannot be squeezed into the dimensions smaller than its wavelength (λ). More specific Abbe, Rayleigh, Sparrow, and Houston resolution criteria show that the limit of lateral resolution is close to a half of the wavelength. The resolution can be further improved by immersing an object in a medium with refractive index (n). This allows achieving the resolution at the $\lambda/2n$ level, but this is a limit of the far-field optics indicating that further increase of the resolution requires different physical principles.

This limitation is the most important bottleneck problem of imaging in nanoscale science and technology, which operates with the objects smaller than 100 nm in size. It means that the visible light with $400 < \lambda < 700$ nm cannot be focused below 100 nm or used for imaging of objects with better than 100 nm resolution. However, the most important objects of nanoscale and life sciences are smaller than 100 nm in size. These include internal cellular structures, DNA and RNA, viruses, proteins, quantum dots and wires, fullerenes, carbon nanotubes, fluorophores, dye molecules, etc.

Due to its fundamental nature, the diffraction limit forms an unavoidable barrier for any far-field imaging system. Increasing the resolution beyond the diffraction limit usually requires either detecting of the evanescent waves which exist only in near-field (in nanoscale proximity to the object's surface), or using strong optical nonlinear effects, or obtaining additional information about objects by other methods. Description of these techniques goes beyond the scope of this book, and it constitutes very active area of modern photonics. One of the examples of importance of this area is represented by awarding of 2014 Nobel Prize in Chemistry to Eric Betzig, Stefan Hell and William E. Moerner for their pioneering work in "super-resolution" fluorescence microscopy.

This book puts forward a more confined, but very important task. It systematically studies the optical properties of mesoscale lenses with dimensions comparable to the wavelength of light: Fresnel zone plates (FZP), photonic crystal structures and dielectric objects with various shapes. All these lenses are designed to focus light in the near-field vicinity of their surfaces and that, in principle, opens a possibility of overcoming the diffraction limit. It should be noted, however, that the conventional analytical methods are not well suited for describing an extremely complicated interplay of various optical effects in mesoscale objects. This interplay includes the coexistence of near- and far-fields, interference of zero-order transmitted and scattered beams, and significant role played by the polarization and directional properties of the incident beams. In addition, the optical near-fields can be resonantly enhanced in such mesoscale objects. This dictates a computational approach of this book based on numerical solution of the Maxwell's equations.

This book is mainly built around the microwave and terahertz applications; however its approach can be also viewed as a scaled model at other frequencies including the optical range. The results indicate that in many cases the subdiffraction-limited beam waists can be realized close to the surfaces of such objects. Although the advancement over conventional diffraction limit is not dramatic (typically limited by $\lambda/3$ in air), this is an important step for developing nanoscience and nanotechnology applications. As an example, such mesoscale structures can be easily fabricated and, in the case of liquid or solid immersion, they can provide nanoscopy with the resolution better than 100 nm using visible light. Such mesoscale lenses can be integrated, for example, into existing semiconductor heterostructure platforms. In addition, these structures can be used as tips of new generations of scanning near field optical microscopes or focusing microprobes for ultraprecise laser surgery.



In the first three chapters, the authors analyze different types of mesoscale lenses. In the fourth chapter, they extend some of their designs to the structures supporting surface plasmon-polaritons (SPPs) with much shorter wavelength compared to that in air. This chapter shows a large potential of such nanoplasmonic structures for increasing resolution. It is likely that the concept of the in-plane SPP curvilinear FZP-like lens will have a significant impact in science and technology.

Throughout the whole book, the reader can recognize that I. Minin and O. Minin are very experienced researchers not only with respect to the scientific quality of their results but especially with regard to the didactic approach of this textbook. The layout of the book is functional and sober, as one expects from a physics monograph. This book is a creative collection of rigorous scientific research and very practical examples. It provides several new insights in the field of optical elements with super-resolution focus and also contains many interesting results that are worth applying in practice, while it is also a source of new and intriguing questions for further research.

Biography

Prof. Igor V. Minin and Oleg V. Minin are a full Professor at Siberian State University of Geosystem and Technologies, Russia. From 1982 to 2001, Profs. Minin were Chief Research Scientist at the Institute of Applied Physics, Novosibirsk, Russia. Drs. Minin received a BA in Physics from the Novosibirsk State University, a PhD in Physics from Leningrad Electro-Technical University in 1986 (Igor Minin) and from Tomsk State University in 1987 (Oleg Minin), and a Doctor of science from NSTU in 2002. Drs. Minin has over twenty years of international industrial and academic experience, and has played key roles in a number of projects, including three-dimensional millimeter-wave real-time imaging and antiterrorism applications. Profs. Minin are the authors or coauthors of approximately 350 research articles, seven monographs (including *Diffractive Optics of Millimeter Waves* (IOP Publisher, 2004) and *Basic Principles of Fresnel Antenna Arrays* (Springer, 2008), and has been awarded 43 patents and inventions. Drs. Minin are the author of several books and book chapters in technical publications, they has been the editor of several books, including *Microwave and Millimeter Wave Technologies Modern UWB Antennas and Equipment* (IN-TECH, 2010) and *Microwave and Millimeter Wave Technologies from Photonic Bandgap Devices to Antenna and Applications* (IN-TECH, 2010). Drs. Minin's research interests are in the areas of diffractive optics and antenna theory (including explosive plasma antennas), millimeter-wave and THz photonics and nanophotonics, information security, detection of hidden weapons as well as development of antiterrorism devices, calculation experiment technologies, and explosive physics. Drs. Minin are a member of SPIE, COST-284, and COST-c0603. Profs. Minin has been an invited lecturer at several international universities and institutions, among them the IEEE Singapore EMCS Chapter, and has served on a number of national and international conference committees. For their work, Drs. Minin were awarded the Commendation for Excellence in Technical Communications (*LaserFocus World*, 2003), and commendation by the Minister of Defense of Russia, 2000. Drs. Minin were included in *Marques Who's Who in Science and Engineering*. Profs. Minin are the reviewers of several international journals including *Applied Physics Letters*, *Optics Letters*, *Optics Express*, *IEEE antennas and Propagations*, *Optics Communications*, *Optical Material Express*, *Sci Reports*, etc.

*** ALL ARE WELCOME ***

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